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Risk Assessment and Safety Analysis in Natural Gas Transmission and Distribution System, Bangladesh

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Abstract

Natural gas is the main resource of energy in Bangladesh. Leakage of natural gas pipelines may cause explosions and fires, ensuing in casualties, environmental damage, and material loss. Economical risk analysis is of great significance for preventing and mitigating such potential accidents. The main purpose of this study was the assessment of the risk of pipelines and safety scenarios to the natural gas transmission and distribution. The study area was centered on Jalalabad Transmission and Distribution System Ltd, a company of Petrobangla in Bangladesh. The research was done on two main bases: Data assortment and Data analysis using the statistical method. For this research, a survey was taken among the personnel on a set of 54 queries categorized into 5 sections like risk sources, work tasks and activities, physical work conditions, job stress of employers and safety and contingency. For data assortment, some statistical analysis methodology was chosen like frequency analysis of risk sources and scrutiny with incidents, work tasks and activities, physical work condition, job satisfaction, safety scenario of this company, ANOVA for determining the relation and significance among the variables, Crosstab and Chi-Square test for determining the dependency with variables. A risk matrix was created for identifying hazards that might be going across the corporate. At last, the authors also provide some proper management and informative mitigation discussions that are discussed to upgrade the safety scenarios of the Natural Gas Transmission and Distribution Company

Keywords: *Gas leakage; Hazards; Safety; Awareness.*

1. Introduction

Natural gas is our country's main source of fuel consumption. Most of the NG, which main component is methane, is transported by pipelines from one location to another. There are three major types of natural gas pipelines ranging in size and inside pressure: gathering systems, transmission systems, and distribution systems. Gathering pipelines extract raw natural gas from production wells; transmission pipelines are large lines that carry long distances of gas around the country, often under high pressure, and transport natural gas to pre-processing or storage facilities. The distribution system is last part of the transportation system. It is the system by which natural gas is transported and distributed to the end-users like homes and industries at relatively low pressure [1]. Natural gas flows through a complex pipeline system that includes elements such as pipes, valves, compression stations, pressure control stations, metering stations, pressure vessels, pulsation dampers, and relief valves that discharge natural gas when safety conditions are not ensured. Nevertheless, the overall risk of failure can be minimized to an acceptable level by opting for effective risk management strategies [2].

A risk assessment study is, therefore, required to identify risk. Identify at first several sources of hazard that present risks to the transmission and distribution of natural gas. The question now is, what is the definition of hazard and risk? Hazard means something that causes harm unless it is regulated or monitored. On the other hand, the risk is a measure of both the probability of an adverse event occurring and the severity of the potential effects if it happens. Probability refers to the possibility of something probable happening. The probability can be expressed as frequency, the likelihood of occurrence over a time interval, or likelihood of condition. The cumulative undesirable outcome of an accident is often stated consequently. The health and safety effects and environmental impacts are usually measured. The consequence reports can be qualitative or quantitative measures of an accident's results. The classical representation of risk in mathematics is [3-4]:

Risk= event probability (or frequency) × severity of consequences (or impacts)

Risk analysis is a systematic and empirical way of predicting and preventing the occurrence of unexpected events by compiling and integrating statistical data regarding potential causes, outcomes, and the probability of resisting the event. A three-dimensional hazard such as ordinary work injuries disaster and major accidents and post-accidental steps are identified [5]. Then it describes the physical conditions of the workplace, the work pressure of the workers, which are negative effects. In many ways, safety and contingency can be defined. Safety means attitude, quality, knowledge, values that industry people share regarding workplace safety. Each industrial company maintains an ideal or not ideal safety instruction in the standard. Safety can be assessed from different points of view for any industrial company, from risk sources, physical workplace conditions, workplace satisfaction, etc.

2. Study area

There are eight company limited, transmission (GTCL, TGTDCL, JGTDCL) distribution (TGTDCL, BGDCL, JGTDCL, PGCL, KGDCL, SGCL) conversion (RPGCL) in Bangladesh [6]. The study area, JGTDSL, is in the north-east of Bangladesh. The thesis work is questionnaire-based, which is related to personal evaluation of assessment risks, work tusk/activities, job satisfaction, their working environment, and safety and contingency measures of their company. For this survey base research work, it is needed actual answer the questionnaire for conducting this research; that's why it is needed for the personnel who are involving with natural gas transmission& distribution companies. It is focused on the native transmission and distribution companies of our country Bangladesh to gather data, but due to a short time for completing this work, it was not possible to collect data from all the companies.

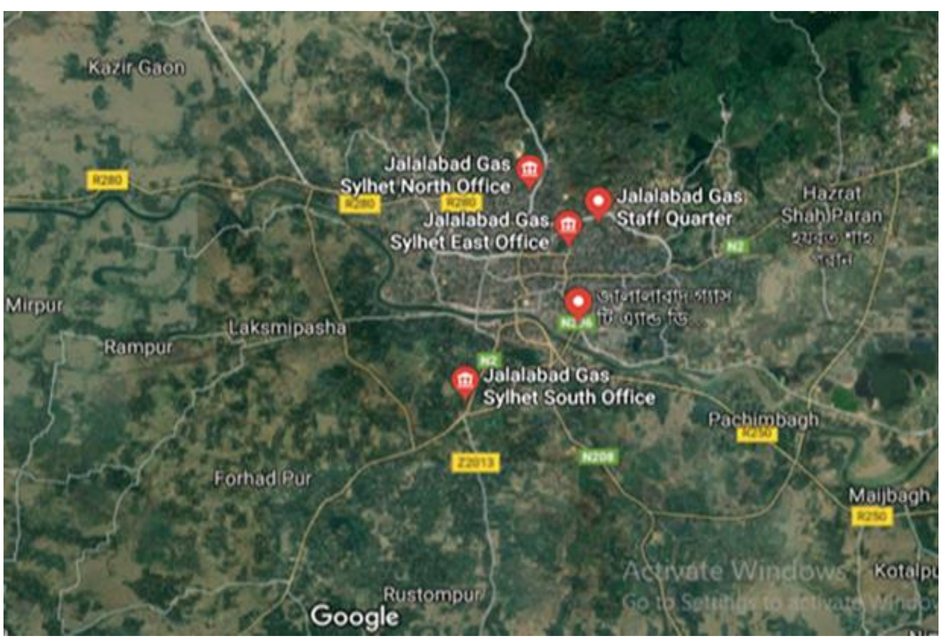

Figure 1. Satellite image of the study area from the google map [7]

3. Methodology

3.1. Questionnaire contents

The research work is related to the analysis of the assessment of risk and safety of the natural gas transmission and distribution, so most consequential questions were selected for analysis of the research. The variables of the questionnaire included the assessment of risk sources (including 9 potential variables sources), work tasks/activities (including 6 individual variables activities), physical work condition (including 2 variables condition), job stress (including 7 individual stress variables), and safety and contingency (including 11 individual safety variables). The questionnaire evaluation procedure was rating based. The personnel taking part in this survey was rated question based on their own opinion. The evaluations included ratings on the five-point rating scale for each test item. The scale for risk assessment ranged from "very safe" to "very unsafe". The job stress scale ranged from "very agreed" to "very disagreed". Physical conditions were likewise measured on a five-point scale ranging from "very good" to "very bad". The scale for safety and contingency aspects ranged from "very ideal" to "not at all ideal".

3.2. Data analysis

Data analysis was used to develop various variables categorical percentage, significance, and dependency for comparing the assessment of different items. The questionnaire was structured. The most answer is the rating base close-ended. Statistical analysis work was done by SPSS (software package for Social Studies) version 13 and Microsoft Office Excel 2013.

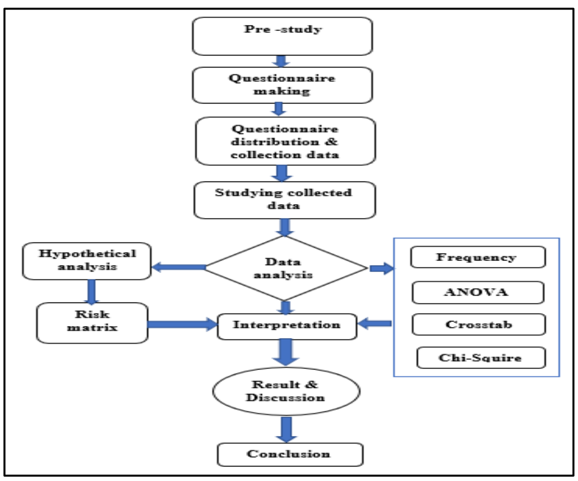

Figure 2. Flowchart of methodology

The statistical analysis is conducted by SPSS Software, and the hypothetical analysis was conducted by Microsoft Office Excel 2013. The frequency was evaluated by SPSS using descriptive statistics of analysis options. It is worked for knowing the percentage feeling safe or unsafe with risk sources, work tasks/activities in the transmission and distribution system, and knowing the physical condition of respondents feeling good or bad. The ANOVA was done to know the data using for analysis is either statistically significant or not significant. Then the risk matrix was developed by Excel 2013, which was analysis cross tabulation from a descriptive analysis option between two dependency variables.

Then, discuss the risk matrix and recommend safety to manage and mitigate the risk.

4. Results and discussions

4.1. The percentage of workers assessment of risk from risk sources

This section represents the individual assessment of threats from different risk sources. It included the percentages of people feeling safe. The risk to the installation of the percentage feeling safe ranges from 23.4% to 97.9% in Table 1. People feeling safer in their view is internal corrosion of pipeline, and feeling more unsafe is excavation damage during another agency's construction. The average percentage of feeling safe is 51.76%, neither is 24.7%, and unsafe is 23.3%. We can decide that the condition of risk sources of this company is good because of the less unsafe percentage.

Table 1. The percentage of workers assessment of risk from risk sources

	Risk sources	% safe*	% neither*	% unsafe*
1	Pipeline failure due to external corrosion	42.6	34	21.3
2	Pipeline failure due to internal corrosion	97.8	2.1	-
3	Excavation damage during another agency's construction	-	23.4	76.5
4	Soil erosion due to flooding, riverbed scouring & rainfall			
5	Pipeline damage due to earthquake	46.8	29.8	23.4
6	Risks from material & equipment failure. (i.e. pressure regulation content of gas system failure, different fittings failure, and valve failure)	23.4	44.7	31.9
7	Improper/incorrect operation	61.7	36.2	2.1
8	Condition of the alarming system before gas release	-		
9	Access to emergency exits/escape route	85.1	14.9	
		83	17	

safe= very safe +safe ; neither*= not safe nor unsafe;, unsafe*= unsafe + very unsafe*

4.2. The percentage of workers feeling safe during work tasks/activities

People feeling safer in their view is facilities to stop gas flow reducing pressure and/or controlling devices, NDT during installing of pipeline/gas stations and feeling less unsafe is NDT or others test of critical regions of pipeline/gas stations during service Table 2. We can decide the work tasks and activities of this company are very good.

Table 2. The percentage of feeling workers assessment during work tasks and activities

	Work tusks/activities	% safe*	% neither*	% unsafe*
1	Facilities to stop gas flow reducing pressure and/or controlling devices	100	-	-
2	Schedule/preventive maintenance of gas stations	70.2	29.8	-
3	NDT during installing of pipeline / gas stations	100	-	25.5
4	NDT or others test of critical regions of pipeline/gas stations during service	53.2	21.3	
5	Checking safety regulator	74.4	2.8	12.8
6	If a pipeline incident is occurred, isolate area and size up incident	80.9	19.1	-

safe= very safe +safe ; neither*= not safe nor unsafe;, unsafe*= unsafe + very unsafe*

4.3. Risk assessment with the perspective of individual department

Data was collected from three departments. The assessment of risk was different from the individual department. The risk sources are divided into three-dimensional categories. There are (1) Ordinary work injuries, (2) Disasters and major accidents and (3) Safety and contingency measure Table 3.

Table 3. Risk assessment with the perspective of individual departments

Percentage feeling safe and strongly safe only						
Dimension		Item	Total	Operation	Planning	Marketing
Ordinary work injuries	1	Pipeline failure due to external corrosion	42.6	33.3	40	28.6
	2	Pipeline failure due to internal corrosion	97.8	100	100	85.7
	3	Improper/incorrect operation	85.1	90	90	57.1
	4	Risks from material & equipment failure. (i.e. pressure regulation content of gas system failure, different fittings failure and valve failure)	61.7	60	80	42.9
		Total	71.78	70.83	77.5	53.58
Disasters and major accident	1	Excavation damage during another agency's construction	23.4	26.7	20	14.3
	2	Pipeline damage due to earthquake	46.8	50	50	28.6
	3	Soil erosion due to flooding, riverbed scouring & rainfall	23.4	25.56	23.33	14.3
		Total	25.5	30	20	14.3
Safety and contingency measures	1	Condition of alarming system before gas release	83	86.7	70	85.7
	2	Access to emergency exits/escape route	46.8	53.4	30	42.9
	3	First aid	51.76	56.7	40	47.63
		Total	60.52	65.6	46.66	58.74

At the assessment, ordinary work injuries feel safe 70.83% from the operational department, 77.5% from the planning department, and 53.58% from the marketing department, which are different from each department, and the marketing department is less satisfied the others. At the sight of disasters and major accidents feel safe 50% from the operational department, 50% from the planning department, and 28.6% from the marketing department, which is a few different from each department. The safety and contingency measures feel at most equal safe among the department. They are all satisfied with these.

4.4. The status of physical work conditions of natural gas transmission and distribution with the environment

During transmitting natural gas in pipelines, high pressure is compressed to control the flow of gas or to maintain the demanding pressure for consumers needed. As a result, some noise and vibration of the pipeline have occurred, which is unexposed with the environment. Sometimes fire or explosion is exposed due to leakage failure of pipelines, which could be harmful to the environment and the worker's life. The responders of this company feel better this condition in Table 4.

Table 4. The percentage of personnel good feeling good or bad with the following statements associated with physical work conditions

Physical work conditions	% good*	% neither*	% Bad*
Noise / vibration	89.4	10.6	-
Fire / explosion	76.66	23.34	-

Very good + good=good, neither*, very bad + bad=bad**

4.5. The personnel satisfaction with job-related statements

The employees of the company were asked some questions related to their work tasks, work environment, and their interactions with other employees to judge their job stress. The job stress is analyzed in the next section; in this section, only the personnel either agreed or disagreed with the questionnaire is identified only. The percentage of agree 73.04% is more with questionnaires than disagree 6.97% in Table 5. In this section, two questionnaires, i.e., organization approaching to transmit instructions and enough freedom to decide on the pace of work, most employees agreed with the questionnaire. We can decide the condition of the job stress of employees is good, which is a good effect on this company. The employees who participated in the questionnaire were all male. It was not possible to contrast between male and female job conditions.

Table 5. The percentages of personnel agreed or disagreed with the following statements associated with the job

	Job related statements	% agreed*	%neither*	% disagreed*
1	My organization approach to transmitting instructions.	89.4	8.5	2.1
2	I have enough freedom to decide on my pace of work.	89.4	8.5	2.1
3	It is easy to predict the expectations put on me by others.	68.5	23.4	8.5
4	I can do my work independently and according to my own views.	66	27.7	6.4
5	I can decide when and how each individual work-task shall be completed.	59.6	29.8	10.6
6	I have a fair opportunity of influencing the decisions to be made by my superiors.	70.2	23.4	6.4
7	My immediate superiors ask for my advice before making their decisions.	68.2	19.1	12.7

4.6. Safety and contingency measures on this company

Safety and contingency measure is the main part of this company. Safety conditions of the company are the probability of risk on the company if any safety condition is damaged. If the safety condition is good, the overall condition of the company is good. We evaluated the personnel overview of the safety measures by asking for ideal and not at all ideal. The percentage of all safety conditions in the company is 69.92% ideal, which is the good condition of this company, and 8.7% is not at all ideal. Use of personal safety equipment, Public awareness program for safety is not ideal for this company, Table 6.

Table 6. The percentage of safety and contingency measure either ideal or not ideal of the company

		%ideal*	%neither*	% not ideal*	Operation% ideal	Planning% ideal	Marketing% ideal
1	Control and inspection routines in the safety work.	87.2	12.8	-	90	70	100
2	Safety instructions.	78.7	21.3		83.4	70	71.4
3	Follow up and measures taken after injuries and accidents have taken place.	80.8	12.8	6.4	76.7	80	100
4	If a pipeline incident is occurred, how much first emergency response from responders managing.	83	14.9	2.1	73.4	100	100
5	Safety training.	46.8	38.3	14.9	53.4	30	42.9
6	Rapid shutdown.	63.8	29.8	6.4	70	60	42.9
7	Protection and safety devices on machines and Equipment.	93.6	6.4		96.7	80	100
8	Marking and signposting for safety instructions.	89.4	10.6		90	80	100
9	Availability of personal safety equipment.	61.7	21.3	17	60	60	71.5
10	Use of personal safety equipment.	34.1	55.3	10.6	40	20	28.6
11	Public awareness. Program for safety	17		44.7	6.7	40	28.6

Ideal= ideal + very ideal, neither*= neither nor not ideal, not ideal= not at all ideal*

4.7. ANOVA analysis

ANOVA is a test of the hypothesis that is appropriate to compare means of a continuous variable in two or more independent comparison groups. In ANOVA analysis, the column called sig. shows whether we have a statistically significant difference in our dependent variable between the categories of the independent variable. The level of significance is at 5 %, which is called the p-value. We need to know the sets of data are statistically significant or not before calculating the reliability factor. We can get a model if the sets of data statistically significant, and it is accepted or otherwise not accepted. In this section, the p-value level of these variables is less than .05. We can evaluate that the variables are significant (Table 7-10).

Table 7. ANOVA analysis for risk sources variables

		Sum of squares	df	Mean square	F	Sig
Between people		46.351	46	1.008		
Within people	Between items	213.827	7	30.547	54.404	0.000
	Residual	180.798	322	0.561		
	Total	394.625	329	1.199		
Total		440.976	375	1.176		
Grand Mean = 3.24						

Table 8. ANOVA analysis for work tusk/activities

		Sum of squares	df	Mean square	F	Sig
Between people		54.485	46	1.184		
Within people	Between Items	44.996	4	11.249	17.998	.000
	Residual	115.004	184	.625		
	Total	160.000	188	.851		
Total		214.485	234	.917		
Grand Mean = 4.05						

Table 9 ANOVA analysis for job stress

		Sum of squares	df	Mean square	F	Sig
Between people		95.131	46	2.068		
Within people	Between Items	10.760	6	1.793	3.194	.005
	Residual	154.954	276	.561		
	Total	165.714	282	.588		
Total		260.845	328	.795		
Grand Mean = 3.86						

Table 10. ANOVA Analysis for safety and contingency

		Sum of squares	df	Mean square	F	Sig
Between people		63.237	46	1.375		
Within people	Between Items	142.742	13	10.980	22.228	0.000
	Residual	295.401	598	0.494		
	Total	438.143	611	0.717		
Total		501.380	657	0.763		
Grand Mean = 3.81						

4.8. Crosstab analysis

Cross tabulation is a method to quantitatively analyze the relationship between multiple variables, also known as contingency tables or cross tabs, cross-tabulation groups variables to understand the correlation between different variables. It also shows how correlations change from one variable grouping to another. It is usually used in statistical analysis to find patterns, trends, and probabilities within raw data [8].

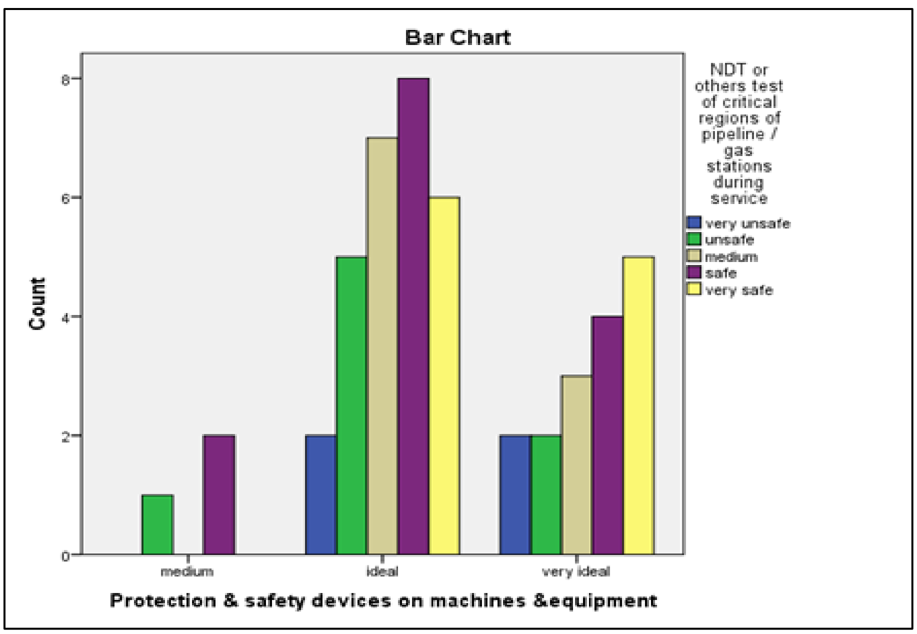

Figure 3. Comparative Bar diagram showing the relationship among variable

4.9. Chi-Square test

The Chi-Square statistic is commonly used for testing relationships between categorical variables. The null hypothesis of the Chi-Square test is that no relationship exists on the categorical variables in the population; they are independent. The Chi-Square statistic is most commonly used to evaluate Tests of Independence when using a cross-tabulation [9].

Table 11. Chi-square tests for evaluating dependency level asymptotic significance (2-sided)

Variables 1	Variables 2	(Pearson Chi-Square)	Result
Control & inspection routines in safety work	NDT or others test of critical regions of pipeline/gas stations during service	0.409	Dependent
Protection & safety devices on machines &equipment	Pipeline failure due to external corrosion	0.017	Independent
Protection & safety devices on machines &equipment	Pipeline failure due to internal corrosion	0.811	Dependent
Following up & measures taken after injuries & accidents have taken place	Excavation damage during another agency's construction	0.406	Dependent
Public awareness program for safety	Excavation damage during another agency's construction	0.128	Dependent
Checking safety regulator	Condition of the alarming system before gas release	0.409	Dependent
Following up & measures taken after injuries & accidents have taken place	Pipeline damage due to earthquake	0.003	Independent

4.10. Risk matrix

A risk matrix is a matrix that is used during risk assessment to define the level of risk by considering the category of probability or likelihood against the category of consequence severity [10]. "Probability" and "severity" is used to quantify the scope of a real or hypothetical safety scenario. Risk matrices are broken into a grid. Matrices grids are usually 5x5, though it can be larger or smaller depending on company needs. The grid is used to assign a "number" to the risk, which is a combination of Probability x Severity and represents the scope of the risk [11]. Some risk matrix is displayed in Figures 4-9.

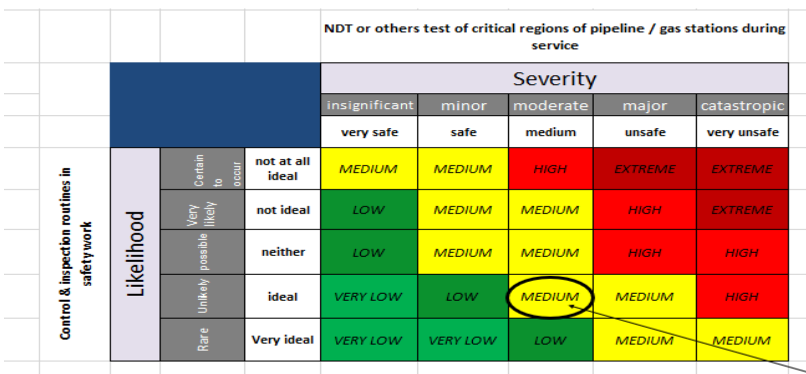

Figure 4. Risk matrix from control and inspection vs. NDT or other tests of the critical region during service

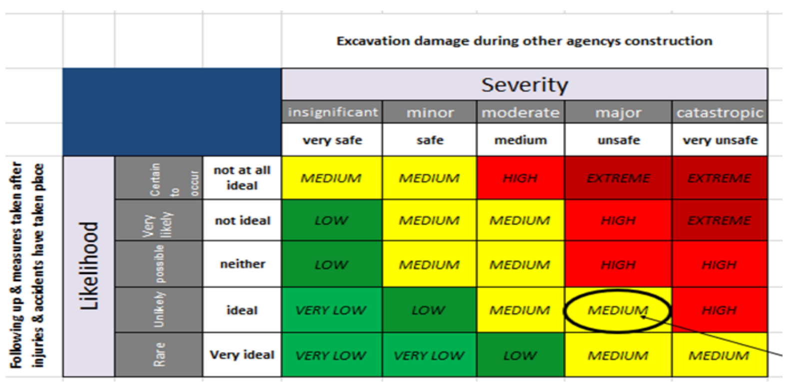

Figure 5. Risk matrix from Following up & measures taken after injuries & accidents have taken place vs. excavation damage during another agency's construction

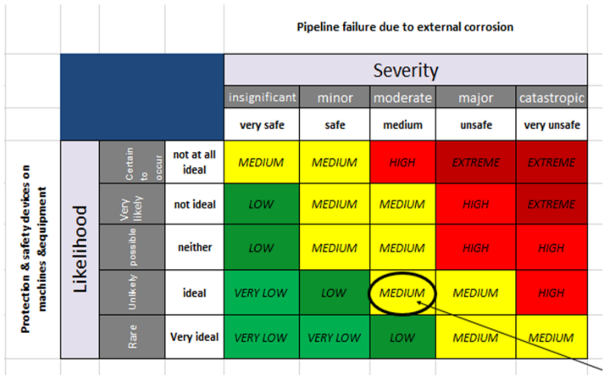

Figure 6. Risk matrix from protection and safety device vs. external corrosion

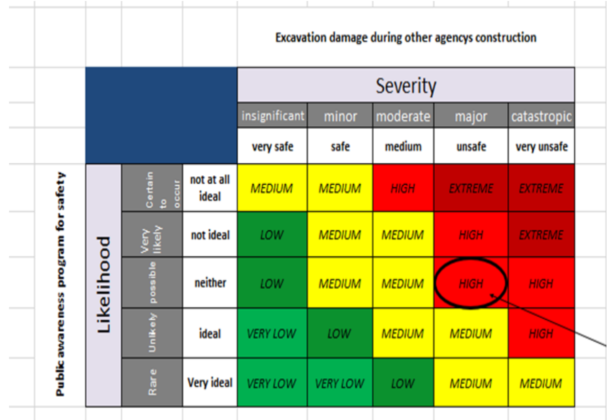

Figure 7. Risk matrix from a public awareness program vs. excavation damage during another agency's construction

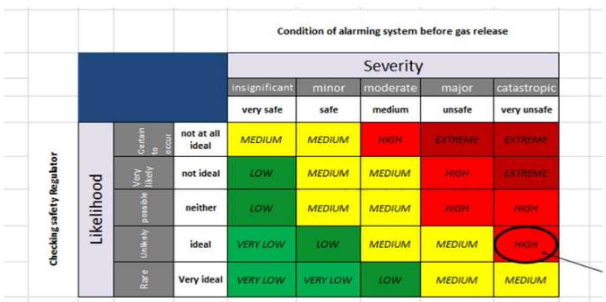

Figure 8. Risk matrix from checking safety regulator vs. alarming system

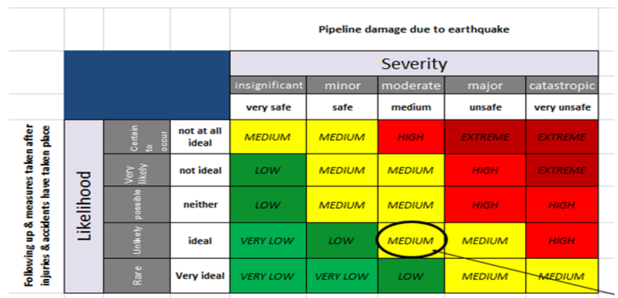

Figure 9. Risk matrix from following up & measures taken after injuries & accidents have taken place vs. pipeline damage due to earthquake

5. Conclusion

Risk assessment of Gas pipelines includes the study of failures and significances of pipelines in terms of possible damage to property, human hazards, and the environment. We found some valuable information by analyzing four statistical methods. Risk matrixes were made based on the probability of risk and severity of consequences and found some important results. Risk matrixes told that the condition was Medium, which action required within an impetuous timeframe to estimate or minimize the risk using the hierarchy of controls. But some risk matrixes told that the condition was ''High" which action needed quickly. The task should not proceed unless the risk is assessed, and control options selected based on the hierarchy of controls. We concluded that the managing system of hazard prevention and safety sceneries which could mitigate the incidents occurring from the hazard of natural gas transmission and distribution.

From this research work, this can be said that People must be aware of all safety signs during excavation. Besides that, OPS and state regulators must continue to support One-Call Centers. Moreover, OPS must respond to the emergency, shout down gas flow if the incident occurred. Emphasize should be given on the continuity of safety training to public and industrial operators.

Acknowledgement

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Acronyms and abbreviations

TGTDCL	*Titas Gas Transmission & Distribution Company Limited.*
JGTDCL	*Jalalabad Gas Transmission and Distribution Company Limited.*
GTCL	*Gas Transmission Company Limited.*
BGDCL	*Bakhrabad Gas Distribution Company Limited.*
PGCL	*Pashchimanchal Gas Company Limited.*
KGDCL	*Karnaphuli Gas Distribution Company Limited.*
SGCL	*Sundarban Gas Company Limited.*
RPGCL	*Rupantarita Prakritik Gas Company Limited.*
SPSS	*Software Package for Social Studies*
ANOVA	*Analysis of One-way Variance.*
NDT	*Nondestructive Testing.*
OPS	*Office of Pipeline Safety.*

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